NWGD factsheet “Drying in the seed processing sector”

Seed drying

Summary

Sowing seeds are dried after harvest to make long time storage possible. Seeds are very sensitive to high temperatures, (too) fast drying and mechanical damage that may cause decline in vigour and viability. Specific slow and gentle drying and handling therefor has been developed. Energy uses and costs are less relevant than the resulting quality of the sowing seeds.

1. The seed sector in The Netherlands

The sector processing and reproduction of seeds contains, simply and solely in The Netherlands, about 300 specialised companies employing 8000 to 10,000 people. Its turnover is about 2 billion Euro and by that the Netherlands is one of the leading countries worldwide. The sector invests about 15% of its turnover in product and process improvements, necessary to maintain their leading position[1,2]. Plantum is the branch organisation for seed companies; see table 1 for the top 10 companies and table 2 for technology providers for this sector.

Table 1:
Top ten Dutch companies producing plant reproduction materials arranged by number of applications for plant breeders’ rights received by CPVO, 2010

Company	Number of applications
1 Rijk Zwaan Zaadteelt en Zaadhandel BV	89
2 Enza Zaden Beheer BV	49
3 Anthura BV	48
4 Nunhems BV	43

5 Dekker Breeding BV	43
6 Fides BV	32
7 Testcentrum voor Siergewassen BV	25
8 RijnPlant BV	22
9 Piet Schreurs Holding BV	21
10 Bejo Zaden BV	20

Source: CPVO Annual Report, 2010.

Table 2:
Main Technology providers for the seed sector [3)]

1. Seed Processing Holland B.V.
2. Germains Seed Technology BV
3. INCOTEC Europe BV

2. What is meant by seed drying?

Drying is the reduction of seed moisture content to the recommended levels for seed storage, using techniques which will not be detrimental to seed viability. In addition, seeds are also dried after wet sterilization and after coating, priming and pelletizing. It is good to distinguish between sowing seeds and seeds for consumption. Many seeds, like grain, rice, soy, are consumed which impose other, less strict obligations on the drying process because they do not have to stay "alive". These drying processes are part of food drying and are not treated here.
Seed drying is a prerequisite for long time storage of seeds, keeping their viability.

Because sowing seeds are living organisms that are stored and treated for later germination, specific demands must be met by the drying processes, like low drying temperatures and gentle handling.

For small quantities, to reach the desired low moisture contents and to increase the speed of the gentle, low temperature drying, silica gel, zeolites or other desiccants (water adsorbing materials) are often applied. For larger quantities, industrial dryers are employed, which must fulfil the same demands concerning mild processing. Also in those applications dehumidified dryer air is often used to speed up drying and to reach a low final moisture content.

For long time storage, the rules of thumb tell that drying to 5% and 7% moisture content is required for small and large seeds respectively. Tables 3 and 4 give the maximum seed moisture contents for long time storage per seed type.

After drying, proper storage is important to keep viability and vigour of the seeds, preferable at RH (Relative Humidity) $\leq$ 50% and certainly $\leq$ 80%. Low temperatures are preferred and in addition dehumidifying of the air in the storage rooms with adsorbent wheels; adsorbents as such; or by cooling/freezing is recommended.

Definition of seed moisture content: (seed weight – dry seed weight) / (dry seed weight) * 100%

Fast drying of sowing seeds is never recommended; slow drying is norm. Because of the low drying temperatures allowed, often dehumidified air is used as drying medium to increase drying speed and reduce final moisture content. RH of 20 to 30% for drying air is often applied with drying temperatures of only 20°C to 30°C, eventually up to 50°C. This results in drying times of 12 to 16 hours or even longer which require drying methods fitted to these long drying times (like drying in vented boxes or bags).

Seeds are very different in size, ranging from the dust-like orchid seeds (1 million seeds per gram) to the largest seeds that weigh over 20 kg. These are extremes; most seeds have dimensions in the order of mm. Many seeds contain food reserves for the first growing phase.

3. Why are seeds dried?

Seeds are dried to store them safely for a long time while keeping their viability and to control the germination time and strength. Fresh seeds that are dried go into physiological dormancy.

Drying after harvest:

Freshly harvested wet seeds are vulnerable to deterioration by bacteria or other spoiling organisms. They normally have a water content of around 24 % and must be dried before storage. Seeds which are dry are much less sensitive to detoriation and will retain their viability for longer periods of storage. In general, it is recommended that for long-term storage, seeds should be dried to 3-7% moisture content. There are some exceptions for which it has been shown that low moisture content causes problems e.g. soybean should only be dried to about 8% moisture content. The drying process should begin as soon as possible after the harvest of the seeds to avoid unnecessary deterioration.

Drying after sterilising / pasteurizing

For killing off any spoiling organism/pathogens seeds are often treated with warm or hot water where after they must be dried before storage. “Free” water can be removed by centrifuges; the ‘bound’ water must be evaporated, thereby keeping mild temperatures and other seed specific demands in mind.

Drying after coating, pelleting and priming

Seeds are often coated with anti-bacterial/anti-fungal additives, colour for recognition, nutritional additives and for ease of handling (increase diameter and weight). The coating is applied wet so that subsequent drying is necessary

4. How should seeds be dried?

4.1 Drying procedure

Several methods are available for drying seeds. Some are more suitable in certain environments and safer for the viability of the seeds than others. Drying seeds in an atmosphere of reduced relative humidity is recommended. The lower the humidity the faster the seeds will dry and the lower their final moisture content. A relative humidity of 10 - 15% and a temperature of 15°C are recommended by the IBPGR Advisory Committee on Seed Storage[6)]: try to obtain these conditions as close as possible. Dehumidification of drying air can be done by adsorbents like silica gel, zeolites etc. To reuse these adsorbents regeneration is required.

When there is no practical experience nor literature data on humidity's and drying time, the operating procedure shown in the scheme of figure 1 can be used. The chosen drying method and equipment will also depend on the equipment available.

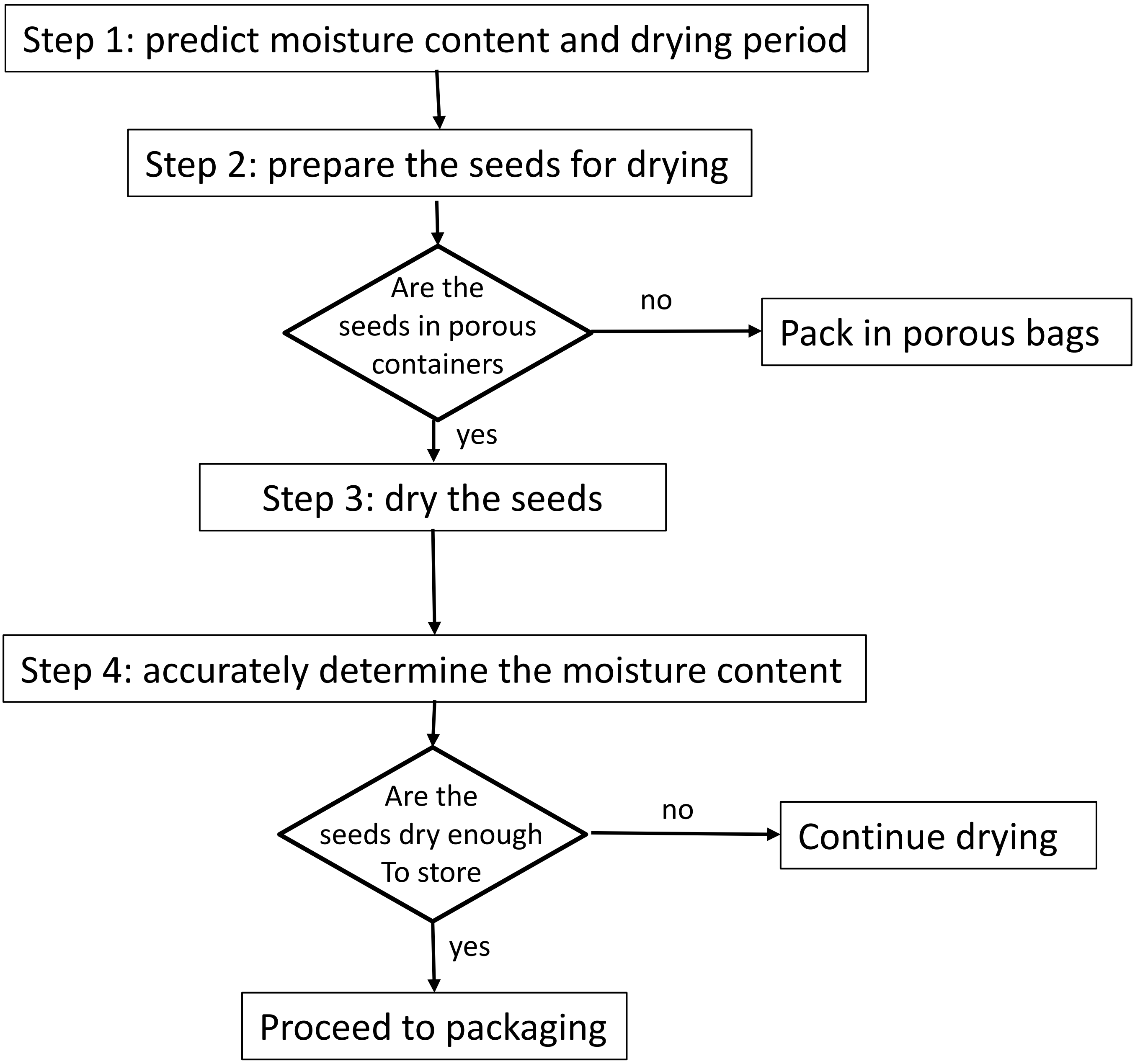

Figure 1: Seed drying procedure

4.2 Prediction of drying period

If there is no previous experience on drying a particular seed species, it may be necessary to do some experimental work to predict the approximate drying period. Seeds dry at an exponential rate until the equilibrium moisture content is reached; see figure 2.

The drying rate behaviour of different seed lots of the same species is fairly constant for seeds dried under the same environmental conditions. The length of the drying period can be predicted in two ways:

4.2.1 Prediction of the required drying period by weight loss

1. Predict the current percentage moisture content and the percentage moisture content required for storage.

2. Weigh the seed sample.

3. Use these three values to calculate the weight of seeds at the required moisture content by using the following formula:

$$\text{Final seed weight} = \text{Initial seed weight} \times \frac{(100 - \text{Initial \% moisture content})}{(100 - \text{Final \% moisture content})}$$

4. Weigh the seed sample at regular intervals during the drying period until the weight of the seeds has reached this calculated value.

<u>Example</u>

1000 g of seeds with 12% moisture content are dried to 5% moisture content. What would be the weight of these seeds after drying?

Substitute the values in the equation above:

$$\text{Final seed weight} = 1000 \times \frac{(100 - 12)}{(100 - 5)} \text{g} = 926.3 \text{g}$$

Therefore, when the initial 1000 g of seeds have been dried to 926.3 g, their moisture content will have decreased from 12% to 5%.

4.2.2 Prediction of drying period from mean drying curves

1. Take at least two lots of seeds of the species and place to dry, using the method that you will use in practice.

2. Remove a sample of seeds and do an accurate determination of moisture content for each seed lot.

3. The mean of the two tests can be used as a guide because other seed lots of the same species should dry at a similar rate.

4. Repeat the determination hourly or daily and plot a graph of the drying curve (mean percentage moisture content against time) for that species under these drying conditions.

5. The work can be repeated with seeds of all species which are of interest and their drying curves plotted for different conditions.

Information on drying periods can also be found in Cromarty, Ellis and Roberts (1982)[7)].

4.3 How to use the drying curves

1. Use the graph that you have prepared for seeds of a species being dried under those conditions.

2. Predict the current percentage moisture content of the seed lot. Select the final percentage moisture content that is required for storage of this species.

3. Find the value for each of the percentage moisture contents on the vertical 'Y' axis, follow this across to the curve and read off the day on the horizontal 'X' axis for each of the moisture contents. The difference between these two values is the drying period in days.

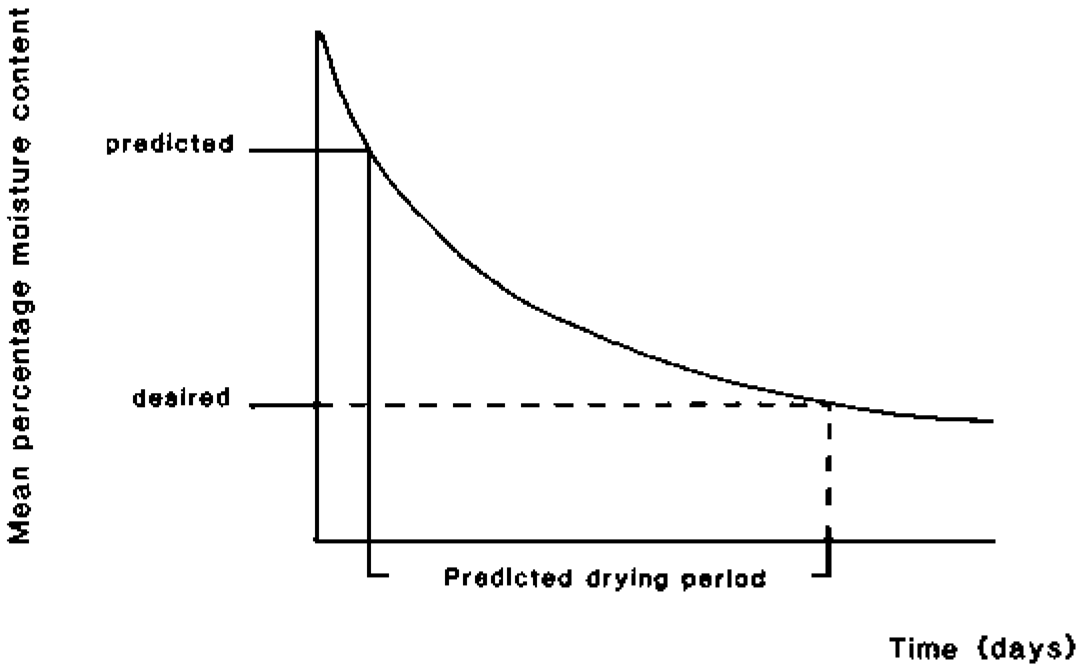

Figure 2: Typical seed drying curve

<u>Seed drying procedures</u>

STEP 1. PREDICT MOISTURE CONTENT AND DRYING PERIOD

1. Use the experience and techniques already described in section 4.2.1 to predict the moisture content of the accessions.

2. Predict the length of drying period required from your previous experience of drying seeds of the same species with similar moisture contents, as already described. Information on drying periods can also be found in Cromarty, Ellis and Roberts (1982)[7)].

STEP 2. DRY THE SEEDS (see section 5 for suitable large scale dryers)

Several methods are available for drying seeds. The safest methods rely on leaving the seeds in an environment of low relative humidity and allowing the seed moisture content to reach equilibrium with this at relatively low temperatures. Seeds will equilibrate with the relative humidity at different rates, depending on species, seed size and conditions. Seeds dry quicker during the first drying stage and more slowly as the low moisture contents suitable for storage are approached. Two common and safe methods are described here:

Choose the best drying method for your own seeds. In tropical countries with high relative humidity, it will be more difficult to hold a drying room at very low relative humidity. A combination of methods is possible. Silica gel can be used after the first drying period if the relative humidity is too high to allow the seeds to equilibrate to low moisture contents.

Do not use sun drying because it is believed to affect long term seed viability of some species. Heated air drying should also be restricted to moderate air temperatures for the same reason.

Aim for 10 - 15% relative humidity and 15°C as the optimum drying conditions.

Use of silica gel, for small amounts of seeds

1. Use deep blue silica gel in an enclosed space, such as a desiccator, can or glass jar with an air-tight seal.

2. Place either the silica gel or the seeds in a porous bag.

3. Use a weight of silica gel equal to the weight of seeds for rapid drying.

4. Place the required weight of silica gel in a desiccator, jar or can with the correct weight of seeds. When using cans or jars make sure that the silica gel is near, but not touching, the seeds.

5. Place the containers in a room held at approximately 15 °C whilst the seeds are drying.

6. Change the silica gel daily or when the colour changes from deep blue to pale blue or pink.

7. Heat the pale blue or pink silica gel in an oven above 100 °C until it turns deep blue again, when it is ready for re-use. Store in an air-tight container.

8. Leave the seeds with fresh changes of silica gel in the container until the moisture content is predicted to be in the range required for storage.

Use of dryers, for larger amounts of seeds; see section 5

STEP 3. ACCURATELY DETERMINE THE MOISTURE CONTENT

1. When you consider, from experience, that the seeds are dry enough, remove a sub-sample from each accession and carry out a moisture content determination.

2. When the moisture content is between 3-7 % for most species, go to packaging. Low moisture contents are detrimental to the viability of the seeds of some crops. These seeds should be treated with care and not dried to low moisture levels, e.g. soybean should not be dried below 8% moisture content.

3. If the moisture content is not low enough, continue to dry for a further period as described above. When the moisture content is predicted to be in the correct range for seed storage, carry out an experimental determination.

Make sure that seeds which have been dried are kept in the drying area or moisture-proof containers whilst tests are carried out to prevent absorption of moisture from the surroundings.

5. Seed drying equipment

Drying is a normal part of the seed maturation process. Some seeds must dry down to minimum moisture content before they can germinate. Low seed moisture content is a pre-requisite for long-term storage, and is the most important factor affecting longevity. Seeds lose viability and vigour during processing and storage mainly because of high seed moisture content (seed moisture greater than 18%). A general overview of drying process and equipment is given by Mujumdar in Handbook of Industrial Drying[18)] and a review of seed drying is given in lit. 9.

5.1 Seed drying with adsorbents - general

Silica gel is an effective desiccant (moisture adsorbing material) for drying seeds. Powdered milk, zeolite and other adsorbents can also be used to reduce the moisture content of seeds directly or of the drying air.
Silica gel and zeolites can be repeatedly reactivated (re-dried) after they have adsorbed moisture. The procedure involves heating the adsorbent to drive off the moisture. Drying/desorbtion must be done in a controlled fashion, otherwise the adsorbing beads (silica gel) will turn black, and the moisture-absorbing capacity of the beads will be destroyed.
There are two methods for reactivating silica gel adsorbents:

1. Oven-drying method:

This method gives the best results, but it takes longer and uses more energy. Set the oven for a temperature of at least 90°C, but no higher than 135°C. Place the silica gel in a thick-walled Pyrex dish, no deeper than one inch, and continue heating until the beads turn deep blue. When drying large quantities (a pound or more), the gel should be stirred occasionally.

2. Microwave-drying method:

The microwave method works much faster but must be monitored more closely to avoid overheating. Set the microwave on medium or medium high. The colour change in the gel can be monitored through the over door, but the gel should be inspected and stirred at the end of each heating cycle. Approximate drying time is eight to twelve minutes per pound of gel, though actual heating time will depend per the type of microwave.

For reactivating zeolite adsorbents, the zeolite beads must be heated up to at least 200°C in an oven. The dry zeolite beads must be stored directly after heating in an air tight container.

5.2 Conventional drying methods

5.2.1 Seed centrifuge

When seeds are very wet the first drying step, to get rid of moisture at the surface of the seeds, can be realised with a centrifuge, which makes the drying process that follows shorter.

Figure 3: seed centrifuge (from Seed processing Holland B.V.)

5.2.2 Drying floors

Newly extracted seeds should pass quickly to drying floors, usually hard platforms that are smooth, tight, and previously cleaned of all impurities. If desired, the platform may be divided into individual compartments to allow different seed collections to be simultaneously dried.
Brick platforms, which are relatively cheap to construct and maintain, can be built to serve as drying floors. Also, tarpaulins spread on the ground under protective covers can be used.

5.2.3 Box dryers against wall.

A flexible drying method consists of boxes with a side opening and a perforated floor where the seeds lay on. These boxes are placed against a vented wall that delivers warm drying air going through the seeds in the boxes. The boxes fit to slits in the wall that are opened when the box is placed against the wall. Boxes can be stacked and coupled and their number is rather unlimited.

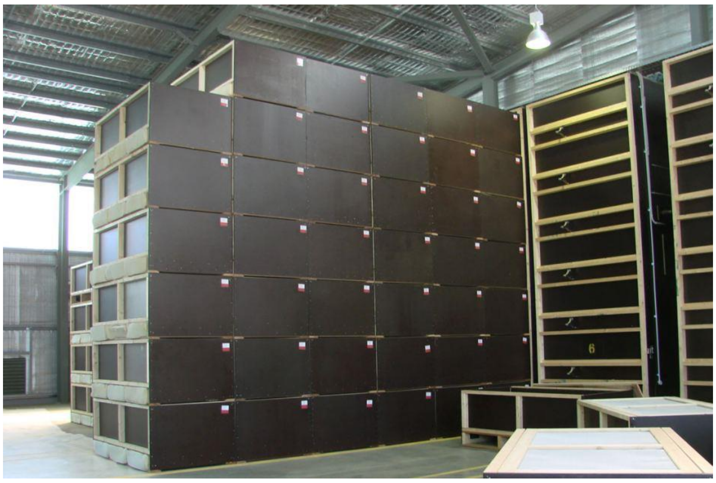

Figure 4: seed drying boxes against a vented wall (at Bejo Zaden B.V.)

5.2.4 Vented boxes with drawers or drums, stationary or mobile

A mobile or stationary box vented with warm air with drawers for seeds to dry. The seeds can be stationary in the drawers or can be fluidized. Also, vented boxes with perforated rotating drums exist, where the seeds tumble in the drums while drying air is vented through the drums. These batch type dryers are appropriate for smaller amounts of different seeds that can be dried fast and flexible.

5.2.5 Fluid bed dryers

In fluid bed dryers, the seeds are on a perforated plate or belt where conditioned drying air is blown through from below, making the seeds fluidise, float, move and turn, which increases the contact between seed and air and thus increasing the drying speed and evenness. Fluid bed dryers can be vibrated to enforce seed transport.

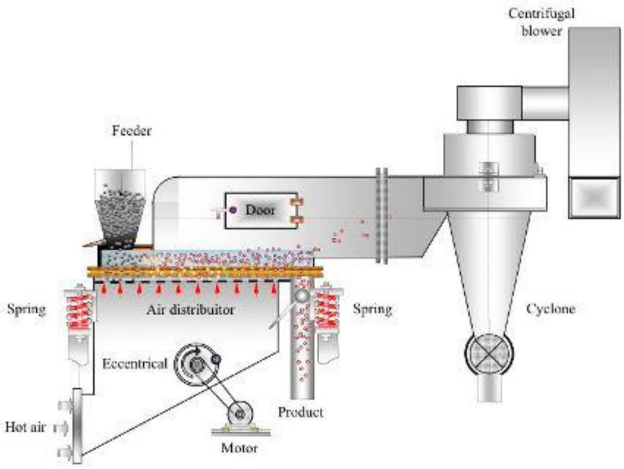

Figure 5: vibrating fluid bed seed dryer (from KTH)

5.2.6 Rotary dryer: perforated or solid drums with seeds and drying air blown through the seeds

In these types of dryers, the seeds are in rotating drums to keep them moving thus guarantying an even drying.

5.3 Dehumidification and temperature control of drying air

For all the dryer types mentioned before the temperature and the humidity of the drying air can be conditioned[10)]. For humidity control the drying air can pass:

a. Adsorbent wheel
b. Adsorbing beads
c. LiBr or other adsorbing liquid salts
d. Sometimes burned rice of charcoal is used.

For temperature control a heater with hot water or steam is used to heat up the drying air.

5.4 Innovative drying methods

5.4.1 Drying with zeolites

A new development for fast and gentile drying based on zeolite beads is developed by the Centor Group[11)],based on ideas from TNO There are essentially 2 embodiments, with direct and with indirect contact.
Direct contact means that the seeds are mixed with dry zeolite beads that adsorb the water from the seeds. By balancing the weight ratio between seeds and zeolite a certain moisture reduction can be achieved. With indirect drying beds of zeolite beads are used to reduce the moisture content of the drying air. The beds of zeolite beads are regenerated with hot air once their adsorbing capacity is reached. Both systems are especially suited for relatively small seed amounts.

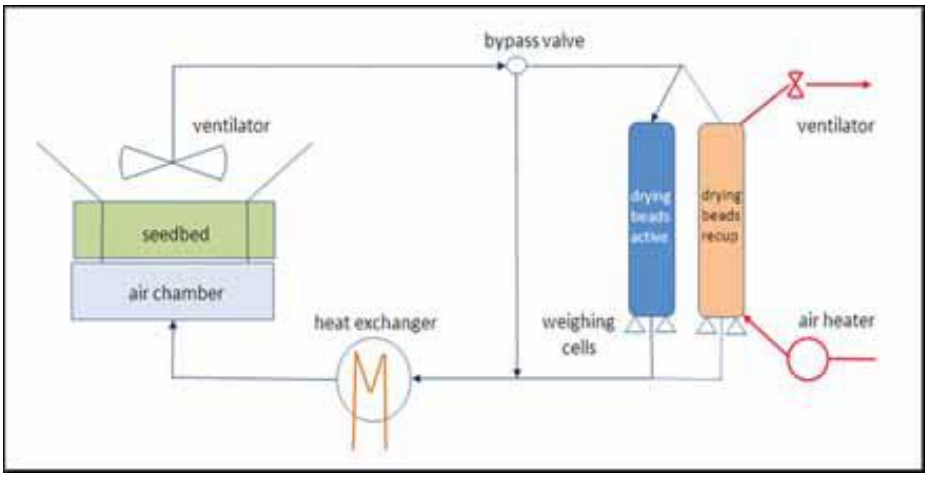

Figure 6: scheme of an indirect zeolite based seed dryer (from Centor Group)

5.4.3 Heat pump seed drying

A heat pump seed dryer is generally a warm air dryer where the air is conditioned by a heat pump system. The cold side of the heat pump cools and thus dehumidifies the drying air that is heated up subsequently by the warm side of the heat pump[12]. Thus, temperature and humidity can be controlled simultaneously and the dryer can be executed with closed air circulation.

6. Energy uses and savings at seed drying

Given the high economic value of germinating sowing seeds there is little attention on the energy costs for drying; a necessary operation to maintain germination and secure long time storage. Data on energy uses are not available. Many seed dryers are based on warm air drying, whose efficiencies range from 50 to 20% or even lower. Energy saving measures are the general ones applicable to drying:

- Prevent over drying, end the drying process if the seeds are dry enough
- Use waste heat if available; this is relatively easy because seeds are dried at low temperatures
- Insulate and close all drying equipment to prevent leakage of warm and/or humidity controlled drying air, and maintain drying equipment properly in this respect

Clean heat exchangers properly; drying seeds may cause dust that can deposit on any surface impeding heat transfer.

7. Conclusions

Drying of sowing seeds is a delicate process because of the sensitivity of seeds for decline of quality and mechanical damage that will reduce vigour and viability. This implies that seeds must be handled and dried gently with care, with low drying temperatures and long drying times. Specific drying equipment therefor has been developed. Energy uses and costs are less relevant than the resulting quality of the sowing seeds.

Table 3: Maximum seed moisture content for seeds stored in sealed containers. The seed moisture percentage of stored seed should not be higher than the values given below [4)]

Vegetable	Seed moisture (%)	Vegetable	Seed moisture (%)
Bean, common	7.0	Leek	6.5
Bean, Lima	7.0	Lettuce	5.5
Beet	7.5	Muskmelon	6.0
Broccoli	5.0	Mustard	5.0
Brussels sprouts	5.0	Onion	6.5
Cabbage	5.0	Onion, Welsh	6.5
Carrot	7.0	Parsley	6.5
Cauliflower	5.0	Parsnip	6.0
Celeriac	7.0	Pea	7.0
Celery	7.0	Pepper	4.5
Chard, Swiss	7.5	Pumpkin	6.0
Chinese Cabbage	5.0	Radish	5.0
Chives	6.5	Rutabaga	5.0
Collards	5.0	Spinach	8.0
Corn, sweet	8.0	Squash	6.0
Cucumber	6.0	Tomato	5.5
Eggplant	6.0	Turnip	5.0
Kale	5.0	Watermelon	6.5
Kohlrabi	5.0	Unlisted	6.0

Table 4: Equilibrium moisture contents of some common crop seeds at 25°C [5)]

Species	Percentage relative humidity					
	15	30	45	60	75	90
Barley (Hordeum)	6.0	8.4	10.0	12.1	14.4	19.5
Beet (Beta)		5.8	7.6	9.4	11.2	
Buckwheat (Fagopyrum)	6.7	9.1	10.8	12.7	15.0	19.1
Cabbage (Brassica)		5.4	6.4	7.6	9.6	
Carrot (Daucus)		6.8	7.9	9.2	11.6	
Cucumber (Cucumis)		5.6	7.1	8.4	10.1	
Egg plant (Solanum)		6.3	8.0	9.8	11.9	
Flax (Linum)	4.4	5.6	6.3	7.9	10.0	15.2
Groundnut (Arachis)	2.6	4.2	5.6		9.8	13.0
Lettuce (Lactuca)		5.1	5.9	7.1	9.6	
Lima bean (Phaseolus)		7.7	9.2	11.0	13.8	
Maize (Zea)	6.6	8.4	10.2	12.7	14.4	18.8
Mustard (Brassica)		4.6	6.3	7.8	9.4	
Oat (Avena)	5.7	8.0	9.6	11.8	13.8	18.5
Okra (Abelmoschus)		8.3	10.0	11.2	13.1	
Onion (Allium)		8.0	9.5	11.2	13.4	
Radish (Raphanus)		5.1	6.8	8.3	10.2	
Rice (Oryza)	5.6	7.9	9.8	11.8	14.0	17.6
Rye (Secale)	7.0	8.7	10.5	12.2	14.8	20.6
Sorghum (Sorghum)	6.4	8.6	10.5	12.0	15.2	18.8
Soy bean (Glycine)	4.3	6.5	7.4	9.3	13.1	18.8
Tomato (Lycopersicon)		6.3	7.8	9.2	11.1	

Turnip (Brassica)		5.1	6.3	7.4	9.0	
Watermelon (Citrullus)		5.1	6.3	7.4	9.0	
Wheat (Triticum)	6.5	8.5	10.4	12.1	14.6	19.8
Winter squash (Cucurbita)		5.6	7.4	9.0	10.8	

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